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LDRD Final Report on a Unified Linear Reference System

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LDRD Final Report on a Unified Linear Reference System

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Abstract

The purpose of the project was to describe existing deficiencies in Geographic Information Systems for transportation (GIS-T) applications and prescribe solutions that would benefit the transportation community in general. After an in-depth literature search and much consultation with noted transportation experts, the need for a common linear reference system that integrated and supported the planning and operational needs of the transportation community became very apparent. The focus of the project was set on a unified linear reference system and how to go about its requirements definition, design, implementation, and promulgation to the transportation community.

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LDRD Final Report on a Unified Linear Reference System

1. INTRODUCTION

This Laboratory Directed Research and Development (LDRD) project was funded for two years beginning January 1995 (FY95) to September 1996 and was designed to advance the state of the art in geographic information science, hence the title "Conceptual Design and Prototyping for a Next-Generation Geographic Information System". The purpose of the study was to describe existing deficiencies in GIS for transportation applications and prescribe solutions that would benefit the transportation community in general. After an in-depth literature search and much consultation with noted transportation experts, the need for a common linear reference system that integrated and supported the planning and operational needs of the transportation community became very apparent. The focus of the LDRD project was set on the unified linear reference system and how to go about its requirements definition, design, implementation, and promulgation to the transportation community.

2. ABSTRACTS OF PUBLISHED REPORTS

The results of this project are documented in the following reports:

- "Geographic Information Systems-Transportation ISTEA Management Systems Prototype Server-Net Pooled Fund Study: Phase B Summary", SNL, ATR, NMSHTD, GPC, 1995
- "Software Requirements Specification for the GIS-T/ISTEA Pooled Fund Study Phase C Linear Referencing Engine", SNL, 1995
- "The Case for a Unified Linear Reference System", SNL, ATR, UW-Madison, USDOT/BTS, ORNL, 1996
- "A Methodology for Design of a Linear Referencing System for Surface Transportation", UW-Madison, 1996

Abstracts of the above reports are presented in the following section.

Geographic Information Systems-Transportation ISTEA Management Systems Prototype Server-Net Pooled Fund Study: Phase B Summary

The Geographic Information System-Transportation (GIS-T) ISTEA Management Systems Server Net Prototype Pooled Fund Study represents the first national cooperative effort in the transportation industry to address the man-

agement and monitoring systems as well as the statewide and metropolitan transportation planning requirements of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). The Study was initiated in November 1993 through the Alliance for Transportation Research and under the leadership of the New Mexico State Highway and Transportation Department. Sandia National Laboratories, an Alliance partner, and Geographic Paradigm Computing, Inc. provided technical leadership for the project.

In 1992, the Alliance for Transportation Research, the New Mexico State Highway and Transportation Department, Sandia National Laboratories, and Geographic Paradigm Computing, Inc., proposed a comprehensive research agenda for GIS-T. That program outlined a national effort to synthesize new transportation policy initiatives (*e.g.*, management systems and Intelligent Transportation Systems) with the GIS-T server net ideas contained in the NCHRP project "Adaptation of GIS to Transportation." After much consultation with state, federal, and private interests, a project proposal based on this agenda was prepared and resulted in this Study. The Geographic Information System-Transportation ISTEA Management Systems Server Net Prototype Pooled Fund Study addresses common issues in applying GIS-T to transportation planning activities.

The general objective of the Study was to develop GIS-T server net prototypes supporting the ISTEA requirements for transportation planning and management and monitoring systems. This objective can be further qualified to:

- Create integrated information system architectures and design requirements encompassing transportation planning activities and data.
- Encourage the development of functional GIS-T server net prototypes.
- Demonstrate multiple information systems implemented in a server net environment.

This Study incorporated Information Engineering and Object-Oriented Analysis methods to define integrated information systems. The Study consisted of three distinct but interrelated phases. Each phase emphasized a different aspect of the research and involved teams with different complementary skills.

The System Architecture Phase (A) focused on defining an information system architecture consistent with Federal Rules 450 and 500 of the ISTEA. This Information Engineering-based architecture consists of high level descriptions of business processes, data, and their interactions. States can use this architecture as the framework for integrated management systems development.

The Analysis and Design Phase (B) analyzed the information framework defined in Phase (A) using the Object-Oriented Analysis methodology. An object model was developed describing efficient and effective transportation planning that take into account four different perspectives simultaneously;

physical, spatial, functional, and temporal. Transportation systems and their components may be integrated and analyzed by their physical characteristics, their location and proximity to each other, the services they provide, and their relationships over time. The object model currently meets the requirements of ISTEA but it is extensible and can be adapted to provide the infrastructure planning necessary for military logistics needs.

The Demonstration Phase (C) coordinated a set of exemplary demonstrations illustrating the models developed in Phases (A) and (B). The Phase C study team, and the public and private sector partners developed demonstrations for display at the end of the study.

Software Requirements Specification for the GIS-T/ISTEA Pooled Fund Study Phase C Linear Referencing Engine

This Software Requirements Specification (SRS) describes the features to be provided by the software for the GIS-T/ISTEA Pooled Fund Study Phase C Linear Referencing Engine project. This document conforms to the recommendations of IEEE Standard 830-1984, IEEE Guide to Software Requirements Specification (Institute of Electrical and Electronics Engineers, Inc., 1984). The software specified in this SRS is a proof-of-concept implementation of the Linear Referencing Engine as described in the GIS-T/ISTEA Pooled Fund Study Phase B Summary, specifically Sheet 13 of the Phase B object model. The software allows an operator to convert between two linear referencing methods and a datum network.

The Case for a Unified Linear Reference System

The transportation industry distinguishes its activities and data into three functionally and institutionally distinct domains. Transportation infrastructure management activities make transport links (*e.g.*, roads, rail lines, transit routes) available for travel. In contrast, civilian and military transport operations focus on finding and using the best transport links. Each of these three transportation interest groups – transportation facility operators, civilian and military transportation users – currently collects and maintains separate, often redundant or inconsistent information concerning the location and status of the transportation system, the vehicles using the system, and the passengers and freight (or materiel) being conveyed.

Although there has been some progress made in integrating data within each domain, little emphasis has been placed on identifying and improving the flow of information between them. Because activities initiated in one domain

affect conditions in the others, defining these flows is crucial to the next generation of planners, traffic managers and customers of transportation services. For example, construction and maintenance activities affect civilian and military route choices and travel times; large scale military movements disrupt civilian travel and have potentially major effects on the infrastructure and so on. This intertwined interest in the transportation system implies the need for data integration not only within each sphere of interest but among the spheres as well. Although recent policy statements by the U.S. Departments of Transportation and Defense and ITS America indicate a desire to combine and share information resources, there are enormous technical and institutional barriers that need to be overcome.

Over the past decade, information analysts in all three domains have independently concluded that location is a primary information need and a central information integration strategy. Knowing where components and events are relative to one another is essential for planning and operational decision-making. Additionally, these locations serve as a significant integrating mechanism when used as the basis for the organization of information and the design of information systems such as GIS-T. Consequently, there has been considerable work done independently in all three domains to define various location reference methods and standards. However, until now there has been no attempt to define a unified approach applicable across all three domains.

Recognizing that there was both a fair degree of overlap among these independent efforts and an opportunity to establish a single location control framework encompassing all three domains, representatives from each domain met to explore such an option. After a day and a half of technical discussions those representatives, along with several invited location experts, concluded that the location control needs of public sector, civilian and military transportation planning and operational activities can be satisfied by a single, comprehensive technical and institutional approach led by the Federal Government and supplemented by state and local transportation efforts.

In addition to this overall finding, the attendees identified several factors impeding the adoption of a single transportation location control strategy, developed preliminary sets of user and technical specifications for a unified approach, identified a research agenda addressing certain technical implications of the specifications and finally generated institutional recommendations for moving forward. This paper is a report of those findings.

A Methodology for Design of a Linear Referencing System for Surface Transportation

The transportation community has recently placed significant emphasis on development of data models, procedural standards, and policies for management of linearly-referenced data. There is an Intelligent Transportation Systems ini-

tiative underway to create a spatial datum for location referencing in one, two, and three dimensions. Most recently, a call was made for development of a unified linear referencing system to support public, private, and military surface transportation needs.

Before a unified linear referencing system can be produced, it must be designed. Before it can be designed, a design methodology must be developed. The linear referencing systems in use today were never designed. They merely evolved. An appropriate design methodology must provide supportable assurances that the linear referencing system will meet the accuracy requirements of users.

Such a methodology for design of the linear referencing system was developed from geodetic engineering principles and techniques used for designing geodetic control networks. The method is founded upon the law of propagation of random error and the statistical analysis of systems of redundant measurements, used to produce best estimates for unknown parameters. A complete mathematical development is provided. Example adjustments of linear distance measurement systems are included. The classical orders of design are discussed with regard to the linear referencing system. A simple design example is provided. A linear referencing system designed and analyzed with this method will not only be assured of meeting the accuracy requirements of users, it will have the potential for supporting delivery of error estimates along with the results of spatial analytical queries.

Modeling considerations, alternative measurement methods, implementation strategies, maintenance issues, and further research needs are discussed. Recommendations are made for further advancement of the unified linear referencing system concept.

3. SOFTWARE

Prototype software of a linear referencing engine was also developed to test the "location reference" portion of the GIS-T/ISTEA Pooled Fund Study object model. The software was written using Borland's Delphi in ObjectPascal. The software is designed to run in a Microsoft Windows 3.x/95 environment and is readily available in a 2-diskette set upon written request to the following address:

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4. CONCLUSION

The mentioned reports describe the need of a unified linear reference system to support the planning and operational needs of the transportation community at all levels of government and the private sector. The concept of a unified linear reference system is not state of the art; but, the requirements analysis, design, and implementation of such a system based on the object-oriented methodology is innovative and necessary. Unfortunately, a third year was needed to fully implement and test these findings. Partners in the transportation industry are being sought to extend the work.

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